The Role of Biogeochemical Dynamics in the Formation of U(VI) Solid Phases

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RESEARCH OBJECTIVES

To assist the U.S. Department of Energy with long-term stewardship issues associated with bioremediation of uranium (U), we seek to define the mechanisms by which microorganisms facilitate the formation of U(VI) solid phases. Under anaerobic conditions, microbial reduction of U(VI) to U(IV) can potentially decrease groundwater U contamination by lowering solubility and by slowing migration through the soil. However, such biological alteration must be considered temporary unless long-term anaerobicity can be maintained. When aerobic conditions return, U(IV) will likely re-oxidize to U(VI), which is generally more soluble and potentially more mobile. The transformation to U(VI)-phosphate solids is of particular interest, since the U(VI) phosphates are the least soluble of the U(VI) solids found in nature.

APPROACH

Bacteria present in soils may play a role in the formation of U(VI)-phosphate solid phases, both because they serve as an available phosphate source and because the cell surface may act as a nucleation site for the reprecipitation of U. We are investigating the ability of some model microorganisms, such as the Gram-positive bacterium, *Bacillus sphaericus*, to complex with U(VI). Ability of *B. sphaericus* to sorb U(VI) has been tested for a wide pH range (pH 3–pH 7), with special attention to the sorption behavior at low concentrations of U, such as would be commonly found in contaminated waste sites. The cell surface group responsible for U(VI) complexation is identified by both laser-induced fluorescence spectroscopy (LiFS) and x-ray absorption spectroscopy (XAS).

ACCOMPLISHMENTS

We find *B. sphaericus* can remove even trace amounts of U(VI) from solution (to below the detection limit of 10-8 moles/L U(VI). Isotherm modeling of U(VI) sorbed onto *B. sphaericus* at pH 5 suggests the presence of greater than one bacterial cell surface site available for U complexation. Both LiFS and XAS yield data that are consistent with the cell surface organic phosphate functional group, called teichoic acid, being the dominant site for U(VI) complexation. U(VI) sorption by *B. sphaericus* is somewhat pH-dependent, with U(VI) sorption capacity increasing initially with increasing pH (from pH 3 to pH 5), and similar sorption capacity seen for pH 5–7.

SIGNIFICANCE OF FINDINGS

Up to this time, no other group has been able to determine U(VI) sorption onto bacteria at the very low and environmentally relevant concentrations of both U(VI) and bacteria used in this study (over 100-fold lower than previous studies). We are the only group testing U(VI) sorption at pH values greater than 5, partly due to the low solublity of U(VI) at higher pH values. Additionally, using a combination of LiFS and XAS to determine the cell surface functional group has led to the strongest evidence to date of organic phosphate serving as the dominant group responsible for U(VI) complexation.

RELATED PUBLICATIONS

Letain, T.E., J.A. Warner, D.K. Shuh, and H. Nitsche, EXAFS study of pH-dependent uranyl adsorption to bacteria. In preparation for Geochimica et Cosmochimica Acta, 2003.

Letain, T.E., T.C. Hazen, and H. Nitsche, *Bacillus sphaericus* surface interactions with uranium (VI) at environmentally relevant concentrations. Appl. Environ. Microbiol., 2003 (submitted).

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